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Elementary Discussion of Roentgenology

MONTGOMERY HOUSTON
Class of 1941

ROENTGENOLOGY today is gradually assuming its rightful rank within the veterinary profession. The vast majority of the X-ray equipment is in the hands of the small animal practitioner where its usage is almost invaluable, and is many times imperative. Practitioners with a large light horse clientele find it a helpful diagnostic agent. As yet, veterinarians in other fields have not found the X-ray practical. The future, however, holds promise of a cheap and convenient means to diagnostic and therapeutic treatment by use of radiogenic

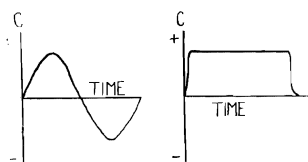


Fig. 1 Fig. 2
C represents current.

salts such as those now being produced by the cyclotron.

The current literature presents an increasing number of articles upon the use of Roentgen rays. It is this writer's purpose in this and the following articles to present to the reader the necessary fundamentals of roentgenology and to offer a simple usable technique for the veterinarian.

Fundamentals of Roentgenology

Like the approach to any other scientific subject, it is necessary to grasp the basic facts concerning the problem at hand. It is only with this firm footing that we may advance to the successful practical use of the X-ray apparatus.

In this discussion it is necessary to re-

view part of the material taken up in physics. There are in general two types of electric current, namely, direct and alternating. The direct current is characterized by a unidirectional current flow; it may fluctuate or be interrupted, but it flows only in one direction. The alternating current is characterized by periodic changes in the direction of current flow. These currents are illustrated graphically in Figures 1 and 2.

In Figure 1 it is noticed that the alternating current polarity (positive or negative) changes in each cycle. The current rises from zero to its peak, drops back to zero, and then repeats this half cycle with the current flowing in the opposite direction. The direct current, however, continues to flow in the same direction since the polarity remains unchanged. A conventional house and business current of 110 volts, 60 cycle, alternating current has a potential difference of 110 volts maintained between the wires with 60 complete cycles (illustrated in Figure 1) occurring each second.

For practical purposes within this discussion, amperage may be defined as the quantity of electricity flowing past any point in the circuit per second. The coulomb is the name of the unit quantity of electricity and the ampere is defined as coulombs per second.

Voltage

Electrical voltage or potential difference measures the work required to carry unit quantity of electricity around the circuit. Thus we speak of a potential difference of 110 volts which means 110 joules (joule = 0.24 small calories) of work are required to carry a coulomb of

electricity around the circuit. In a high voltage circuit more work is required to transport each unit quantity. The most practical means for generating a high potential current is by means of the step-up transformer shown in figure 3. This type of apparatus will function only

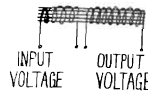


Fig. 3.

Input voltage of 10 volts with one ampere through four turns of wire induces a current of 20 volts with one-half ampere through eight turns of wire.

when there is a change in the input current. Therefore it is necessary to use either an interrupted direct current or an alternating current. The output of a transformer is always an alternating current as illustrated in Figures 4 and 5.

The next portion of this basic X-ray apparatus to consider is the tube itself. The simple X-ray tube requires two voltages, one, a low voltage to send current through the filament, or heater,

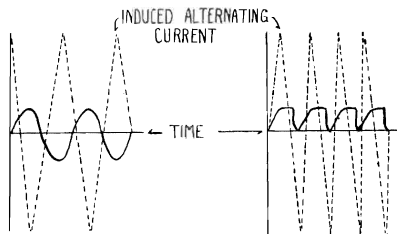


Fig. 4.

Fig. 5

In fig. 4 the wavy line represents the input alternating current and in fig. 5 the interrupted direct current.

and second, a high voltage used in the actual production of X-rays. There are on the market many brands of tubes. The details of construction vary with the price, the purpose they are to be used for, and the general classification to which they belong. The most popular types of tubes today are modifications of the Coolidge tube.

Simple Tube

A simple self rectifying tube and wiring circuit is shown in Figure 6. Upon referring to this we find a transformer capable of delivering both a 12 volt heater current and the high tension of 50,000 volts, or 50 kilovolts (50 KV) to the terminals of the Coolidge tube. This simple glass tube contains a target, T, of heavy copper with the projecting face cut off at an angle of 45°. In this sloping face is imbedded a small piece of tungsten metal, flush with the surface. Opposing this is the heater filament, F, and

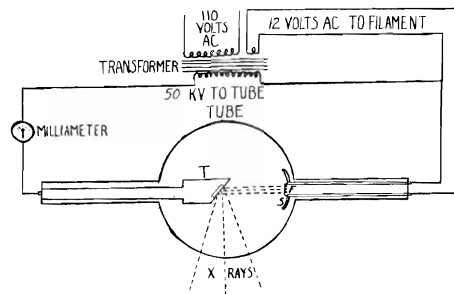


Fig. 6.

the focusing shield, S. The tube is evacuated to a high degree. An enlarged section of the target and filament is shown in Figure 7.

When in action, the tungsten filament is heated to a white heat by the current supplied by the 12 volt winding of the transformer. At this temperature, electrons present in the metal acquire sufficient kinetic energy so that some of them escape to the space surrounding the filament and constitute a "cloud" of negative particles. When a high voltage such as 50 KV is impressed between the target (anode) and the filament (cathode) these free negative charges are accelerated toward the target and impinge thereon giving rise to a great deal of heating affect and some X-rays. The focusing shield, S, being part of the cathode carries a negative charge and aids in confining the electron stream to a small region on the target. By changing

the position of this shield the area of the so-called focal spot can be changed giving rise to what is known as the "broad focus" or "sharp focus" tubes.

Cathode Rays

The electron stream traveling toward the target is termed cathode rays. From the physical standpoint these electrons are tiny charged particles which because of their extremely small mass attain speeds of $\frac{1}{3}$ to $\frac{1}{2}$ that of light (186,000 miles per second) when accelerated by a potential difference of 50,000 volts applied between the tube electrodes. Upon striking the tungsten faced target these electrons are suddenly stopped with the result that a small part of their energy of flight is converted into X-rays.

When using an X-ray tube in a self rectifying circuit the anode (target) wire

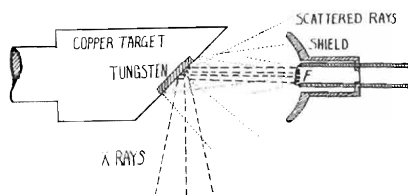


Fig. 7.

will, of course, be positive with respect to the cathode only half of the time. Consequently electrons are striking the target only half the time with the result that the X-ray output is half what it would be if the target was maintained positive continuously.

X-rays are identical in nature with visible light. The only distinction is in their wave length. X-rays are of the order 10^{-8} cm. as compared to visible light whose wave lengths are thousands of times longer. A justifiable simile useful in picturing the production of X-rays would be found in the case of a man throwing a handful of BB shot against a drum. The moving shot (electrons) strike the taut drumskin and set up sound vibrations (X-rays) which are audible. The shot and sound waves produced are related, but are not the same.

So it is with the cathode rays producing the X-ray.

Thus far fixed voltage conditions impressed upon the tube have been considered. In actual practice, the voltage on the high tension side is varied in all but the smallest outfits to meet the requirements of the situation. The kilovoltage determines the velocity of the cathode ray stream. The higher the KV, the faster the electrons travel and the shorter and more penetrating are the X-rays produced. Useful voltages range from 20 KV to 1000KV, or from very soft to very hard rays. The X-ray output from a tube varies directly with the electron current or amperage through that tube. This current is customarily measured in milliamperes (1/1000 ampere). Dosage or exposure time to X-rays varies inversely with the tube current, i.e., if this is doubled, the same amount of X-rays will be emitted in one half the time.

Cooling Devices

We have mentioned previously that the main affect of the bombardment of the target by the cathode ray stream is the production of heat at the target surface. If the tube is overloaded by the impressed high tension current too long even at the normal rating, or if this is increased over the tube's limit, the anode will probably melt. Special devices are incorporated in various tubes to prevent overheating. The target is generally imbedded in a massive copper block which has good heat conducting properties. Frequently in large outfits, water or oil is pumped through the interior of the target to carry away the heat. Other tubes have a heavy copper or alloy stem terminating outside of the tube in a series of radiating fins to aid in rapidly dissipating the heat. A rotating target tube provides an offset circular target of tungsten which is continually rotated by means of an induction motor located within the sealed tube, thus constantly presenting a fresh cool face to the cath-

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ode rays. Another popular type, termed the line focus tube, changes the angles of the target to approximately 20° and the cathode ray stream is projected as a rectangle while the X-rays emitted have a focal spot in the form of a square. Figure 8 explains this graphically. The

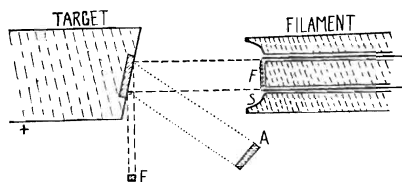


Fig. 8.

A, actual focal spot area; E, effective focal spot.

larger area exposed will accommodate more heat and consequently will allow a larger energy input to be used without an increase in the size of the effective focal spot.

Focal Spot Sizes

It may be well to include a brief discussion of focal spot sizes since they are important in securing the best detail under given conditions. In general a tube has one size of focal spot with the exception of certain expensive double tubes. A focal spot is the projected image of the area upon the target from which the effective X-rays are produced. The smaller the dimensions of this spot the sharper will be the detail in the subsequent picture. Figure 9 shows this diagrammatically with the error magnified. If we refer to what was said previously regarding heat produced at the target, it is evident that a small focal spot cannot stand as heavy a cathode ray bombardment as the larger spot. In veterinary roentgenology the small focal spot tube is generally synonymous with one or several of the following four conditions: (1) low kilovoltage, (2) low milliamperage, (3) short available exposure time, and (4) sharp detail. Large focal spots are used generally in conjunction with higher power inputs, long exposure times, and always less sharp

rendition of detail. Actual focal spot sizes range from 1.5 millimeters to 9 millimeters in tubes on the market today. They may be circular or square depending on the tube design.

Up to this point reference has been given to a simple all glass tube as in Figure 6 for the sake of clarity. However, in the past 10 years many types of shockproof and special units have been made available. Improved technique in the sealing of metal to glass and better insulating materials have helped make this possible. As a result there are now numerous types of tubes in which the body is metal with X-ray transparent windows sealed on. Some small units have the transformer, choke coils, and tube all built into a compact unit sealed in oil. In all but the very small units, the operator has to contend with a number of controls. The small models spoken of have but an ON and OFF switch with a split second timer incorporated. Lar-

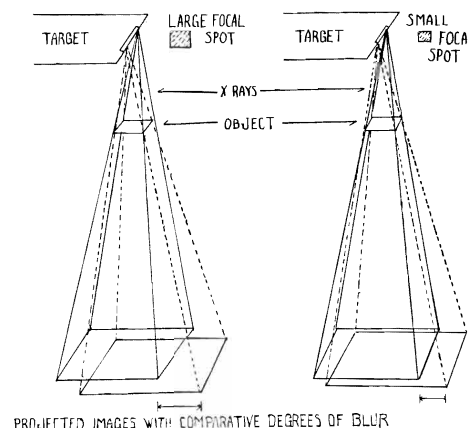


Fig. 9.

ger units present variable controls for the milliamperage and kilovoltage, a filament switch, and a hand switch with a timer wired in to control the high tension current production. Still larger models may have a line current compensator and a variable filament rheostat. In general, a milliammeter is built in which indicates the average current which is present on the high tension side. The kilovoltage settings are predetermined at the factory.